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Water Activities in the Kerala Khondalite Belt

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The determination of $a(\text{H}_2\text{O})$ and $a(\text{H}_2\text{O})$ gradients in granulite terrains can provide important constraints on their petrogenesis [1,2,3]. In this study, we calculate $a(\text{H}_2\text{O})$ in various rock types of the Kerala Khondalite Belt (KKB) and evaluate the granulite-facies metamorphism of the region in light of this information.

Two of the major rock types of the KKB contain mineral assemblages that permit the characterization of $a(\text{H}_2\text{O})$. The charnockites contain $\text{bt} + \text{qtz} + \text{opx} + \text{kfs} + (\text{grt} - \text{ilm} \pm \text{gr})$ and the khondalites contain $\text{bt} + \text{qtz} + \text{sil} + \text{grt} + \text{kfs} \pm (\text{crd} - \text{spl} - \text{ilm} - \text{gr})$. These two assemblages define the equilibria: (R1) $2 \text{Phl} + 6 \text{Qtz} = 3 \text{En} + 2 \text{Kfs} + 2 \text{H}_2\text{O}$ and (R2) $\text{Phl} + 2 \text{Qtz} + \text{Sil} = \text{Prp} + \text{Kfs} + \text{H}_2\text{O}$, respectively, and can be used to calculate $a(\text{H}_2\text{O})$, provided that pressure and temperature are known and the relevant thermodynamic data and activity-composition models are available.

Geothermobarometric studies [4] indicate that the entire KKB was metamorphosed at relatively uniform conditions of 5.5 kb and 750°C. Therefore, all calculations were made at this pressure and temperature. The position of the Mg-end-member reactions were calculated using thermodynamic data from the internally consistent data set of Holland and Powell [5]. It is possible to make the calculated position of R1 agree with the experimental bracket of Bohlen et al. [6] at 5 kb and $X(\text{H}_2\text{O}) = 0.35$ by adjusting the thermodynamic values of Phl [7]. Because recent calorimetric measurements [8] suggest that the $\Delta H_{\text{Phl},298}^f$ listed in Holland and Powell [5] is correct, we have chosen to increment the $S_{\text{Phl},298}^\circ$ until the calculated position of R1 agrees with the experimental bracket. The shallower slope of R1 calculated with this larger $S_{\text{Phl},298}^\circ$ is in better agreement with the slope of R1 (at $X(\text{H}_2\text{O}) = 1$) determined by Wood [9].

$a_{\text{Phl}}^{\text{Mica}}$ and $a_{\text{En}}^{\text{Opx}}$ were calculated using ideal on-sites mixing

models [10,11]. The $a_{\text{Kfs}}^{\text{Afs}}$ was assumed to equal $X_{\text{Kfs}}^{\text{Afs}}$, where $X_{\text{Kfs}}^{\text{Afs}}$ was determined from the composition of coexisting plagioclase at 750°C according to the model of Stormer [12]. The $a_{\text{Prp}}^{\text{Orl}}$ was calculated using the model of Newton et al. [13].

The results of the calculations are shown in map-form in Fig. 1. The charnockites give an average $a(\text{H}_2\text{O}) = 0.27 \pm 0.05$ (1 σ) and the khondalites an $a(\text{H}_2\text{O}) = 0.26 \pm 0.06$ (1 σ). The striking feature is the uniformly low $a(\text{H}_2\text{O})$ recorded over a large region. This uniformity is in marked contrast to a number of other granulite terrains where significant gradients in $a(\text{H}_2\text{O})$ have been documented over a kilometer or even a meter scale [2,3].

Two lines evidence suggest the uniform $a(\text{H}_2\text{O})$ of the KKB rocks were not caused by the extraction of a partial melt. First, within each rock type, $a(\text{H}_2\text{O})$ shows no obvious correlation to bulk compositional variables such as silica content, Fe/Mg ratio or $a(\text{TiO}_2)$. Thus, "restite-rich" assemblages record approximately the same $a(\text{H}_2\text{O})$ as more leucocratic assemblages. Second, there is a remarkably good agreement between $a(\text{H}_2\text{O})$ in the charnockites and khondalites. If this agreement is correct then it would seem highly fortuitous that two contrasting rock types, which encountered different melting reactions, partially melted to yield identical $a(\text{H}_2\text{O})$.

The simplest interpretation of the $a(\text{H}_2\text{O})$ data is that the rocks of the KKB equilibrated with a low $a(\text{H}_2\text{O})$ fluid that had a roughly constant composition throughout the region. The patchy replacement of garnet-biotite gneiss by coarse-grained charnockite along deformation zones and foliation planes provides field evidence for this fluid-present metamorphism [14,15]. It is the opinion of the authors that the low $a(\text{H}_2\text{O})$, presumably CO_2 -rich, fluids were introduced from deeper levels. However, a model invoking internally-derived fluids, such as those generated by the reaction $\text{bt} + \text{qtz} + \text{gr} = \text{opx} + \text{kfs} + \text{v}$ [16], possibly under conditions of $P_{\text{fluid}} < P_{\text{lithostatic}}$ [14], would also be consistent with the $a(\text{H}_2\text{O})$ data, provided that these fluids were sufficiently water-poor.

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42

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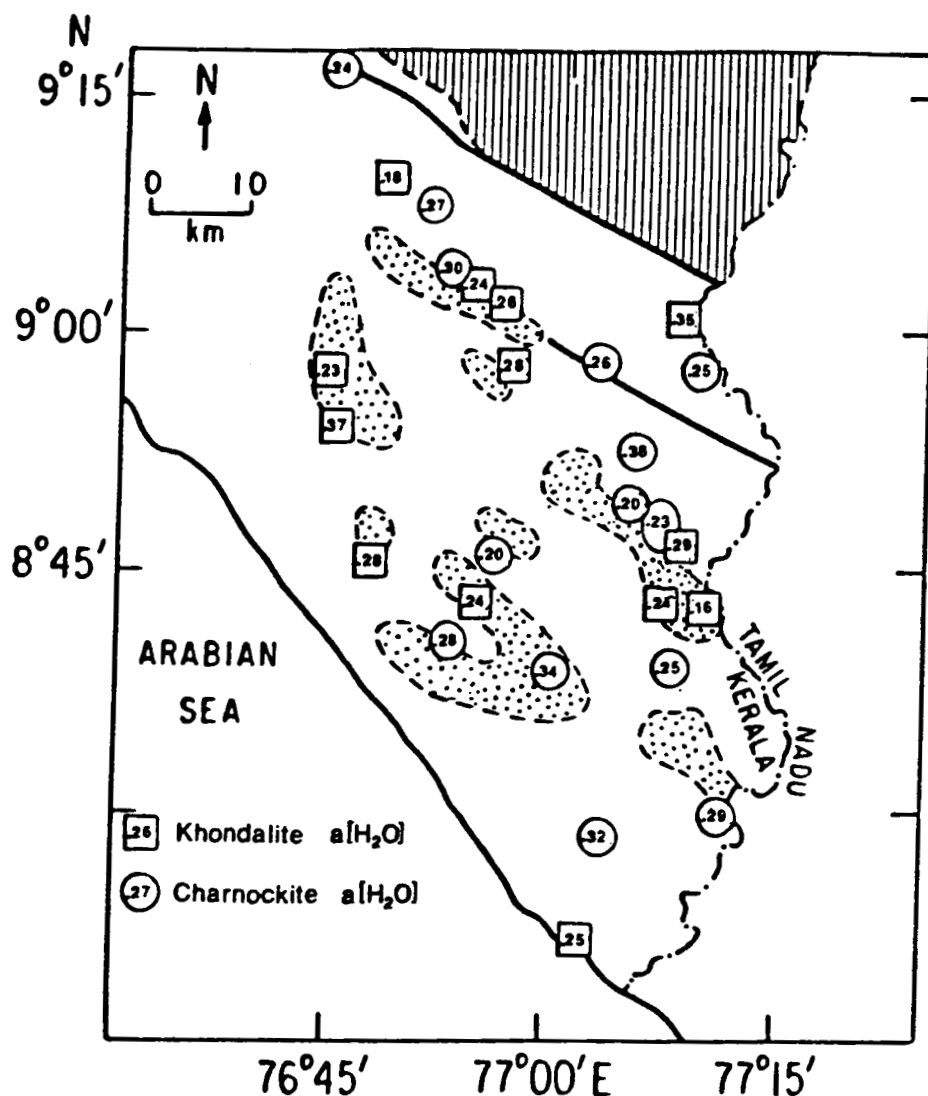


Fig. 1. Calculated $a(\text{H}_2\text{O})$ values in charnockites (circles) and khondalites (squares) of the Kerala Khondalite Belt.